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(54) A CORE FOR A SANDWICH STRUCTURE

(71) We, SOCIETE NATIONALE INDUSTRIELLE AEROSPATIALE, of 37 Boulevard de Montmorency, Paris, France, a French Body Corporate, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to the construction of cores for "sandwich" structures.

As used hereinafter the term a "sandwich structure" is used to denote a structure having two thin walls interconnected by a core of material which is formed as an open structure similar to a honeycomb structure whereby the sandwich structure has a high strength to weight ratio when compared to a a solid structure.

Sandwich structures of the aforementioned kind are used as partition walls, as heat and sound insulation, as components of monocoque assemblies, and as mechanical reinforcing or force-transmitting elements used in aircraft, cars, building and shipbuilding.

There are various known sandwich structures, made of plastics or metal. The known sandwich structures differ mainly in the shape and arrangement of the core.

In the most well-known structure, the core has a honeycomb form. The core comprises a number of hexagonal cells having generatrices perpendicular to the walls. The aforementioned core has the disadvantage of having broken lines where fatigue breaks can easily begin. Furthermore, when curved panels are manufactured, undesirable compensation curves or "anticlastic" curves appear to an appreciable extent. It is difficult to machine cores of this kind. They can be made from only a reduced number of materials, since small-radius folds produce cracks or hammer-hardening.

In other known embodiments, the cores are made of rectilinear strips intersecting perpendicularly edgewise. It is very difficult to shape the last-mentioned cores into curved panels. When the cores are made of metal, the two sides have to have a flanged edge so that the strips can be welded to the surfaces; this increases the weight of the assembly and reduces its capacity to withstand the wrenching forces of the surfaces.

It has also been proposed to form cores from strips having generatrices parallel to the surfaces. The last-mentioned cores have major disadvantages in that they have low crushing strength, they cannot be given a double curvature, and it is difficult to machine them and prepare large panel surfaces.

The invention, which obviates these disadvantages, relates to a novel kind of core for a sandwich structure, the core being made up of thin metal or plastics strips laterally connecting the inner surfaces of the walls to be assembled. The arrangement of the strips provides a number of advantages.

Accordingly we provide a core, for a sandwich structure, made up of thin strips of material, the edges of which are adapted to be secured to the two outer walls of the said sandwich structure, wherein the strips are regularly corrugated and disposed parallel to one another, each corrugation of the strips forming a continuous curve having an inlet width (a) which is narrower than its maximum width (b) measured in the longitudinal direction of the corrugated strip, all the convex portions of the corrugations being in contact with both sides of the corrugation inlets in a similar adjacent strip.

Consequently, the corrugated strips substantially comprise a succession of substantially cylindrical portions or folds, so that adjacent strips can be secured together at their generatrices in contact.

A core for a sandwich structure can also be formed by juxtaposing the strips without securing them together, thus reducing the rigidity of the structures without appreciably decreasing their strength, so that they can be formed into panels which curve in both the longitudinal and the lateral direction of the strips.

The dimensions of the corrugations in the

strip and the radius of curvature of the corrugations can vary.

In an advantageous embodiment, the radius of curvature of circle portions of the corrugations is constant, selected in dependence of the strip material, so that the said strip material does not crack or suffer hammer-hardening during manufacture.

The circle portions of the corrugations, each of which extends for more than a semi-circle and which have alternately opposite curvature, can follow uninterruptedly on the strip or can be separated by flat portions of strip.

The following description, together with the figures of the accompanying drawings, show clearly how the invention can be embodied. In the drawings:

Figures 1 and 2 are plan views of two exemplary cores formed from juxtaposed corrugated strips;

Figure 3 is a plan view of a preferred embodiment of the strip;

Figs. 4 and 5, in a manner similar to Figs. 1 and 2, are plan views of examples of cores made from circular portions of corrugated strips.

Referring now specifically to the figures two adjacent strip A_1, A_2 shown edgewise in Fig. 1 comprises identical corrugations *1a*, *1b*. The width *a* of the inlet 2 to each corrugation is less than the maximum width *b* of each corrugation, the dimensions *a* and *b* being measured in a substantially longitudinal direction of the strip. Since the corrugations are equal, symmetrical and round, the convex portion of each corrugation *1a*, *1b* in strip A_1 can press when the strips are juxtaposed, against the edges of the inlets of the corrugations *1c* of adjacent strip A_2 to form closed compartments or cells 3, having a curved periphery with two cusps thereby to form a core.

To this end, as shown in Fig. 2, the corrugation *1a* on one side of the strip need not be the same as corrugations *1b* on the other side thereof; it is merely necessary that all the corrugations *1a* for example on one side of the strip should be identical.

In the cores shown in Figs. 1 and 2, the curves, which in the strip *per se* bound portions of a cylinder are clearly variable. However, the minimum radii *r* of the said curves should not be less than the minimum folding radius of the material used to make the strip, since otherwise the strip material may be damaged during manufacture by cold-hammering and as a result would crack.

If the other radii of curvature of the said curves are appreciably larger than *r* (Fig. 1) the resulting compartments or cells 3 may have a fairly large volume (area Fig. 1) so that the core may become insufficiently strong.

Fig. 3 shows an advantageous embodiment of the invention for obtaining compartments or cells having a very small surface, wherein the radius of curvature R of the cylindrical surfaces, shown as circles, is constant and preferably just above the minimum folding radius of the strip.

Circle portions 5, 6 of strip A, extending over more than a semi-circle, have centres on two parallel lines 7, 8, spaced apart a distance *d*. The diameter of the circle portions 5, 6 is ϕ, and clearly $\phi=2R$.

The distance between the centres of adjacent circle portions 5.5, 6.6 on the same line is *e* where $\phi<e<2\phi$. The distance *d* between lines 7, 8 is such that

$$d=\sqrt{\phi^2-\frac{e^2}{4}},$$

since the distance *c* between two successive circle portions 5, 6 on lines 7, 8 is such that $c=\phi$, since the circle portions are tangentially connected.

In Figs. 3 and 4, each circumference of a circle portion extends for but three-quarters of a circumference.

In Fig. 5, $e=\sqrt{3}\phi$ and

$$d=\frac{\phi}{2},$$

this is the preferred case in which the centres of all the circle portions are disposed at the apices and centres of a regular hexagonal mesh 10 of side *f*, and each circumference of a circle portion extends for two-thirds of a circumference. However, the distance C may be greater than ϕ if the circle portions, instead of being directly connected, are separated by straight portions at a tangent to the two circle portions, thus avoiding sharp folds.

Cores shown in Figures 4 and 5 have corrugated strips A_1, A_2 juxtaposed with respect to one another so that the convex portions of the corrugation are at a tangent to the inlets of the concave portions, where the distance *f* between the centres of the circle portions in two different but adjacent strips such as A_1, A_2 is equal to ϕ.

A core made up of a large number of the aforementioned corrugated strips in juxtaposition is disposed between two facing surfaces of two sheets of a substance which is usually the same as that used for the strips to make a sandwich structure. In the case of a metal structure the core is secured to the sheets by any known method such as diffusion welding, electric welding or adhesion. The resulting core can first be impregnated e.g. by immersion in a varnish, thus connecting the components and protecting them against corrosion.

A sandwich structure comprising a core according to the invention has numerous advantages including the following:

In the case more particularly shown in Figs. 4 and 5, in which all the strip portions are curved and thus have the maximum crushing and bending strength, the structure has a smaller apparent density than a structure of similar strength comprising a "honeycomb" core. The resulting assemblies are lighter.

More particularly, the depth *h* (Fig. 4) of the compartments or cells formed by the juxtaposition of corrugated strips is much greater than in the case of honeycomb structures, and the compartments or cells are disposed so that shearing stresses are efficiently transmitted at right-angles to the strips, without it being necessary to secure the strips to one another.

Since the compartments or cells are essentially circular, the structure is less anisotropic than a honeycomb structure, more particularly when the strips are secured together. Furthermore, the local resilience of the strip is increased by the continuous curvature of the cross-section, even if the strips are not joined together. Finally, as already stated, when the structure is of metal, the constant radius of curvature of the corrugated strips reduces the hammer-hardening of the material when it is being corrugated, thus improving the fatigue strength and the resistance to corrosion and creep.

The aforementioned advantages also apply when the structure is being assembled, more particularly when a join between strips is deliberately avoided. It is then much easier to secure the core to the surfaces by welding, inter alia by "diffusion" welding. Similarly, all the joins, i.e. the strip-strip and strip-wall joins, can be made by the "immersion" method which has hitherto been used only for reinforcing or protecting the strip material.

The resulting cellular structure can be more easily shaped than most known cellular structures, owing to the marked decrease in "anticlastic" curvature that is to say when applied to double curvatures transverse to each other, the curvatures being in opposite directions, convex to its length, and concave to its breadth or *vice versa*. Consequently a core according to the invention can be made from substances which are difficult to shape.

Cellular structures according to the invention can be used in the construction of buildings or vehicles, more particularly aircraft. More particularly, when made from refractory metals such as titanium, they can be used in the manufacture of supersonic heavier-than-air machines.

WHAT WE CLAIM IS:—

1. A core, for a sandwich structure, made up of thin strips of material, the edges of which are adapted to be secured to the two outer walls of the said sandwich structure, wherein the strips are regularly corrugated and disposed parallel to one another, each corrugation of the strips forming a continuous curve having an inlet width (*a*) which is narrower than its maximum width (*b*) measured in the longitudinal direction of the corrugated strip, all the convex portions of the corrugations being in contact with both sides of the corrugation inlets in a similar adjacent strip.

2. The core as claimed in Claim 1, wherein the strips are merely in contact without being fixed together.

3. The core as claimed in Claim 1, wherein the strips are assembled along the region in which they are in contact.

4. The core as claimed in Claim 1, wherein the corrugations are the same on both sides of the strip and their minimum radius of curvature is at least equal to the minimum folding radius of the strip.

5. The core as claimed in Claim 1, wherein the curved portions of the corrugations have a circular cross-section of constant radius, extending for more than a semi-circle.

6. The core as claimed in Claim 5, wherein the strip cross-section comprises a series of opposite circle portions extending for three-quarters of a circle.

7. The core as claimed in Claim 5, wherein the strip cross-section comprises a sequence of opposite circle portions extending for two-thirds of a circle.

8. A core substantially as hereinbefore described with particular reference to, and as shown in, the figures of the accompanying drawings.

9. A sandwich structure including a core as claimed in any of the preceding claims.

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Fig.1

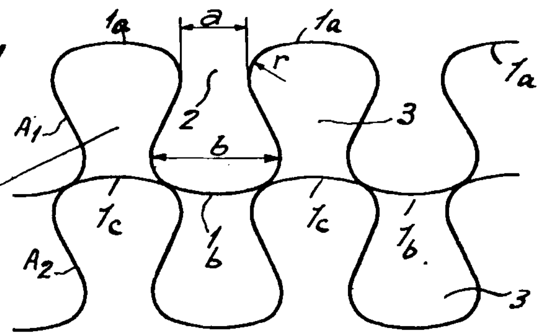

Fig.2

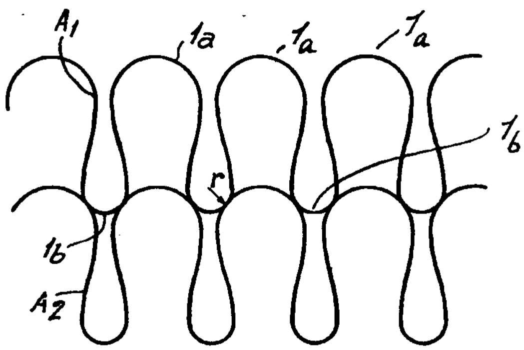

Fig. 3

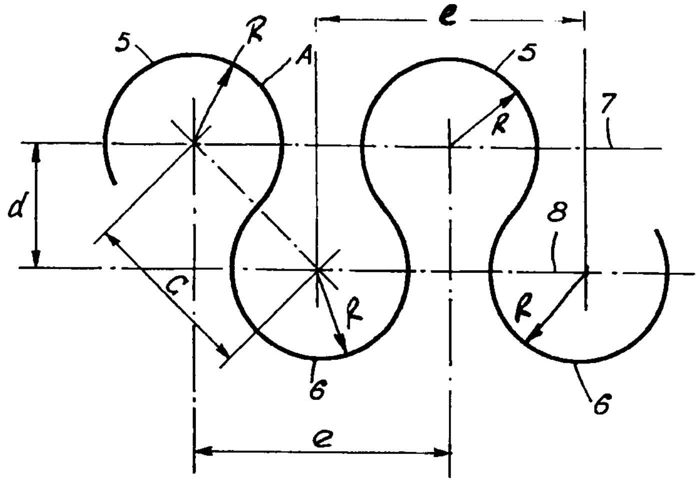

Fig. 4

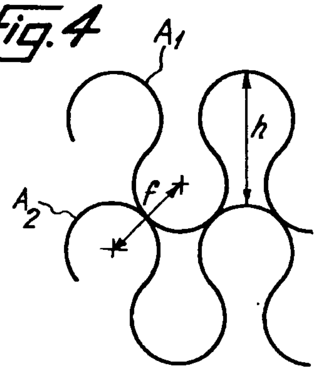

Fig. 5